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Determination of High Risk of Adverse Impact Zone

Naval Air Warfare Center Weapons Division
China Lake Ranges

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Executive Summary

The NDAA 2011 Section 358 directs the Secretary of Defense to "identify geographic areas selected as proposed locations for projects filed, or which may be filed in the future, with the Secretary of Transportation pursuant to section 44718 of title 49, United States Code, where such projects could have an adverse impact on military operations and readiness and categorize the risk of adverse impact in such areas as high, medium, or low for the purpose of informing early outreach efforts".

The Naval Air Systems Command (NAVAIR) coordinated with the Office of the Chief of Naval Operations (OPNAV), Navy Secretariat and Office of the Secretary of Defense (OSD) to jointly formulate the concept of a High Risk of Adverse Impact Zone (HRAIZ) for the R-2508 Complex due to significant and unavoidable mission impacts from wind turbine development at these locations.

Airborne radar testing is a core Naval Air Warfare Center Weapons Division (NAWCWD) mission area that is threatened by the proliferation of wind turbine development in and around the R-2508 Complex. Current wind energy developments limit the NAWCWD ability to conduct airborne radar testing and validation towards the southwestern portion of the complex. Other planned wind energy projects threaten the NAWCWD ability to test in other directions.

For many years, NAWCWD has been concerned about the adverse impacts wind turbines have on airborne radar testing conducted at the China Lake Ranges (CLR). Initial concerns arose in the 1980s when test aircrew noticed adverse effects on airborne radar testing concurrent with the development of the Tehachapi wind resource area. The concern heightened in 2008 with a proposed project to develop a small size wind turbine farm in the Eastern Mojave Desert. NAWCWD staff worked closely with the project sponsor and planners to explain Navy concerns and reasons for opposing the proposal. To strengthen its position, NAWCWD conducted a series of airborne radar flight tests which conclusively demonstrated wind turbine impacts on its operations. The recorded flight test data was further compared to and found consistent with computer model results.

In contrast, numerous solar energy systems currently operate within the footprint of the R-2508 Complex with no mission impacts documented to date. Solar energy, including photovoltaic and concentrated solar power systems, is generally compatible with the current NAWCWD mission and is expected to remain so into the foreseeable future. The results of the radar flight tests provided the Navy the convincing argument needed to result in the proposed wind energy project being replaced by a photovoltaic solar energy project that was compatible with the NAWCWD mission.

This experience and the increasing interest in wind energy development caused NAWCWD to become more proactive in its approach to protecting the airborne radar research, development, acquisition, test & evaluation (RDAT&E) mission. Accordingly, NAWCWD coordinated with the Office of the Chief of Naval Operations (OPNAV) and Office of the Secretary of Defense (OSD) to jointly formulate the concept of a High Risk of Adverse Impact Zone (HRAIZ). In addition to the HRAIZ, OSD suggested consideration of the "curtailment" option for mitigation,

requiring the wind turbine operators to shut down the systems when the Navy is scheduled to conduct certain radar test events.

Subsequently, OSD requested the Massachusetts Institute of Technology Lincoln Laboratories (MIT LL) to provide a third-party review of the Navy flight test findings and investigate additional mitigation options. MIT LL validated the correlation of flight test data and computer modeling results, supported the HRAIZ approach, and provided other potential mitigation measures for the Navy to evaluate relative to the mission. The HRAIZ proposed in this report is approximately 74,370 square miles. However, based upon land use and ownership, only 667 square miles have development potential for current wind turbine technologies.

The Navy and MIT LL concur that airborne radar testing at the CLR will be significantly impacted by any wind turbines operating within the HRAIZ proposed in this report. This conclusion is supported by detailed analysis of flight test data and computer modeling.

1. Background

For many years, Naval Air Warfare Center Weapons Division (NAWCWD) has been concerned about the adverse impacts wind turbines have on airborne radar testing conducted at the China Lake Ranges (CLR). Initial concerns arose in the 1980s when test aircrew noticed adverse effects on airborne radar concurrent with the development of the Tehachapi wind resource area in the southwestern portion of the R-2508 Complex. Due to data corruption caused by the turbines, NAWCWD was forced to cease airborne radar testing oriented towards Tehachapi and implement time-consuming methods to eliminate the data corruption issue. This was a feasible approach in the 1980s because the radars of that period were not as capable or integrated with other mission systems as they are in more modern aircraft such as the F-18 E/F and F-18G. However, eliminating data corruption on these modern radar systems presents a greater challenge because a technical solution is not available, workarounds will likely increase costs, and test schedules for developmental testing of future weapons systems will likely be impeded. Therefore, this is no longer a viable option.

The Navy's concern with wind turbines significantly heightened in 2008 with a proposed project to develop a small-size wind turbine farm in the Eastern Mojave Desert. NAWCWD staff worked closely with the project sponsor and planners to explain Navy concerns and reasons for opposing the proposal. The Navy also conducted a series of radar flight tests to demonstrate the impacts wind turbines have on airborne radar systems. These tests were conducted in 2009 with Navy F-18 aircraft and consisted of multiple test events involving radar pointed toward the Tehachapi wind turbines from various altitudes, aspect angles, radar modes, and other operational variables of interest. The Navy also ran computer models based upon ground truth data provided by the wind turbine developers, such as model number, location, size, blade speeds, and manufacturer. The ground truth data was also used to determine how well the predicted results compared to those actually observed, collected, and analyzed during flight tests. Flight test data confirmed negative impacts on the airborne radar systems and corroborated with computer model results.

With this information, the Navy made a convincing argument that prompted the developer to replace the proposed wind energy project with a photovoltaic solar energy project that was more compatible with the NAWCWD mission. In fact, numerous solar energy systems currently operate within the footprint of R-2508 Complex with no mission impacts documented to date. Solar energy, including photovoltaic and concentrated solar power systems, is generally compatible with the NAWCWD mission and is expected to remain so into the foreseeable future.

In 2011, the Air Force Flight Test Center conducted similar flight tests on various models of aircraft and their results supported the 2009 Navy findings. Due to differences in test requirements, the areas in which wind turbines impact the Air Force radar testing are different than those that impact NAWCWD testing. This proposed HRAIZ addresses the NAWCWD issues only.

This experience and the increasing interest in wind energy development caused NAWCWD to become more proactive in its approach to protecting the airborne radar research, development,

acquisition, test & evaluation (RDAT&E) mission. Accordingly, NAWCWD coordinated with the Office of the Chief of Naval Operations (OPNAV) and Office of the Secretary of Defense (OSD) to jointly formulate the concept of a High Risk of Adverse Impact Zone (HRAIZ). In addition to the HRAIZ, OSD suggested consideration of the "curtailment" option for mitigation, requiring wind turbine operators to shut down the systems when the Navy is scheduled to conduct certain radar test events.

OSD subsequently requested the Massachusetts Institute of Technology Lincoln Laboratories (MIT LL) to provide a third-party review of the Navy flight test findings and investigate additional mitigation options. MIT LL validated the correlation of flight test data and computer modeling results, supported the HRAIZ approach, and provided other potential mitigation measures for the Navy to evaluate relative to the mission.

2. NAWCWD Airborne Radar Test Mission

NAWCWD is chartered to develop, test, and evaluate current and new weapon systems for Fleet readiness, and airborne radar testing is one of its core mission areas. The CLR is a Major Range Test Facility Base (MRTFB) and Base Realignment and Closure (BRAC) designated Weapons and Armaments Center of Excellence. The combination of its unique infrastructure and open air test space provides a full spectrum of aircraft RDAT&E, including airborne radar test capabilities, for the joint services and allied governments. This test capability and validation requirement is critical to Fleet readiness and cannot be severed from the NAWCWD mission. The primary focus of airborne radar testing at the CLR includes:

- *Developmental testing* to evaluate emerging radar technology and ensure that systems under test satisfy precise system requirements.
- *Specification testing* to measure radar system performance and determine if it satisfies procurement specification requirements. These tests require a "pristine" environment (no data corruption) where the experimental variables can be strictly controlled.
- *Operational testing* to determine if the radar system performs to design expectations under realistic operational conditions and to verify the system is ready for Fleet introduction. The weapon system platform must be tested under all environmental conditions to identify any system vulnerabilities.

NAWCWD conducts approximately 700 hours of developmental radar testing each year with specification testing being a subset of this total. All developmental radar testing requires a pristine test environment with specification testing requiring the largest uncorrupted test area. Examples of specific airborne radar tests conducted by NAWCWD include:

- Detection of high, low, and co-altitude targets that vary in size from smaller than fighter aircraft and cruise missile to large aircraft
- Track testing against maneuvering and slow speed targets
- Ground moving targets

- Target breakout
- False alarm testing
- Air Combat Maneuvering

Accomplishing these test objectives requires the tests to be conducted in a prescribed manner while keeping the experimental variables under strict control. For example, one element of specification testing must be accomplished with only the intended target in the radar line of sight (LOS). Any other objects moving within the radar LOS, such as wind turbines, can invalidate specification test results. The R-2508 Complex is the only pristine area with the required test infrastructure and airspace to effectively conduct airborne radar testing. Test measurements provide the Department of Defense (DoD) with decision-quality data to ensure major weapons systems acquisitions are meeting defined requirements and support systems development. The R-2508 Complex is depicted in Figure 1. The complex includes the Naval Air Weapons Station (NAWS) CLR, Fort Irwin, and Edwards Air Force Base (AFB). The Nevada Test and Training Range (NTTR) is also shown, and its relevance will be discussed later in this report.

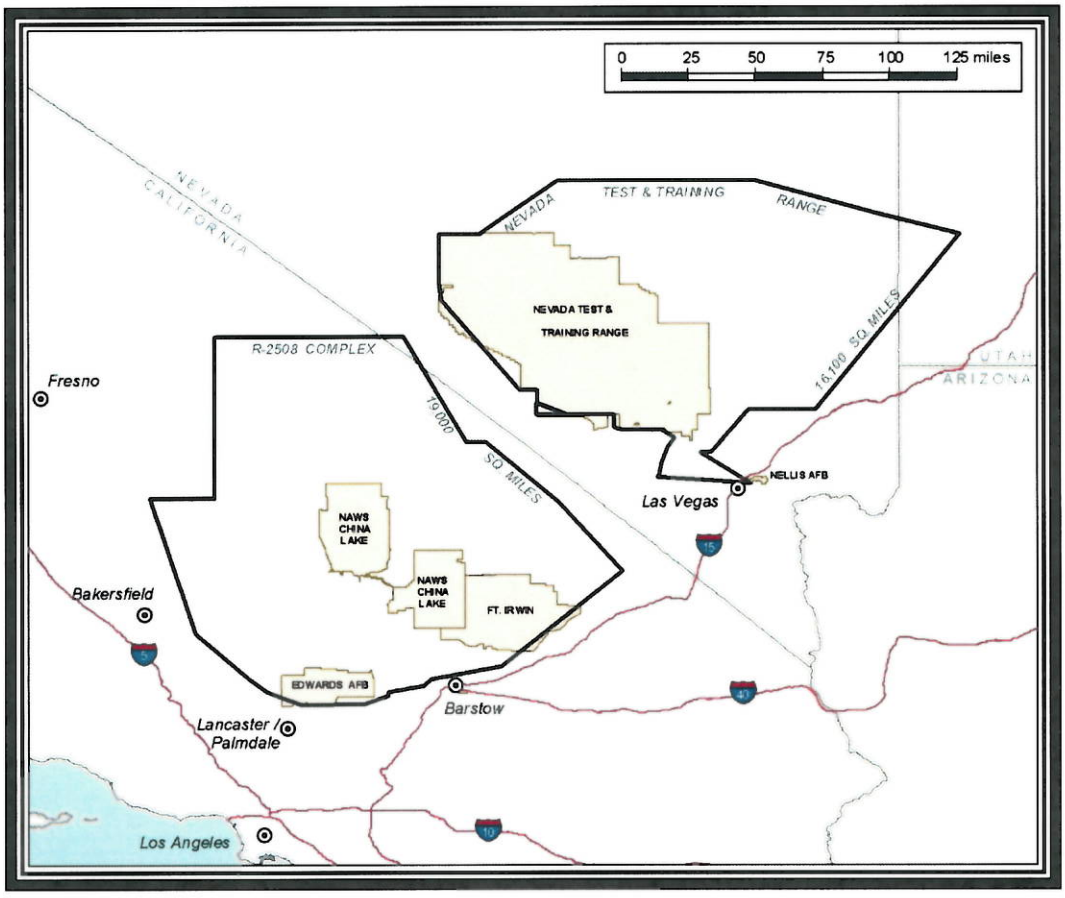

Figure 1: R-2508 Complex and Nevada Test and Training Range

3. Operational Impacts

Wind energy development in and around the R-2508 Complex currently limits the ability to conduct airborne radar testing towards the southwest, and other planned wind energy projects threaten the ability to test in other directions. Figure 2 indicates existing operational wind turbines and proposed wind turbine development sites. Also shown is the HRAIZ, which will be discussed later in this report.

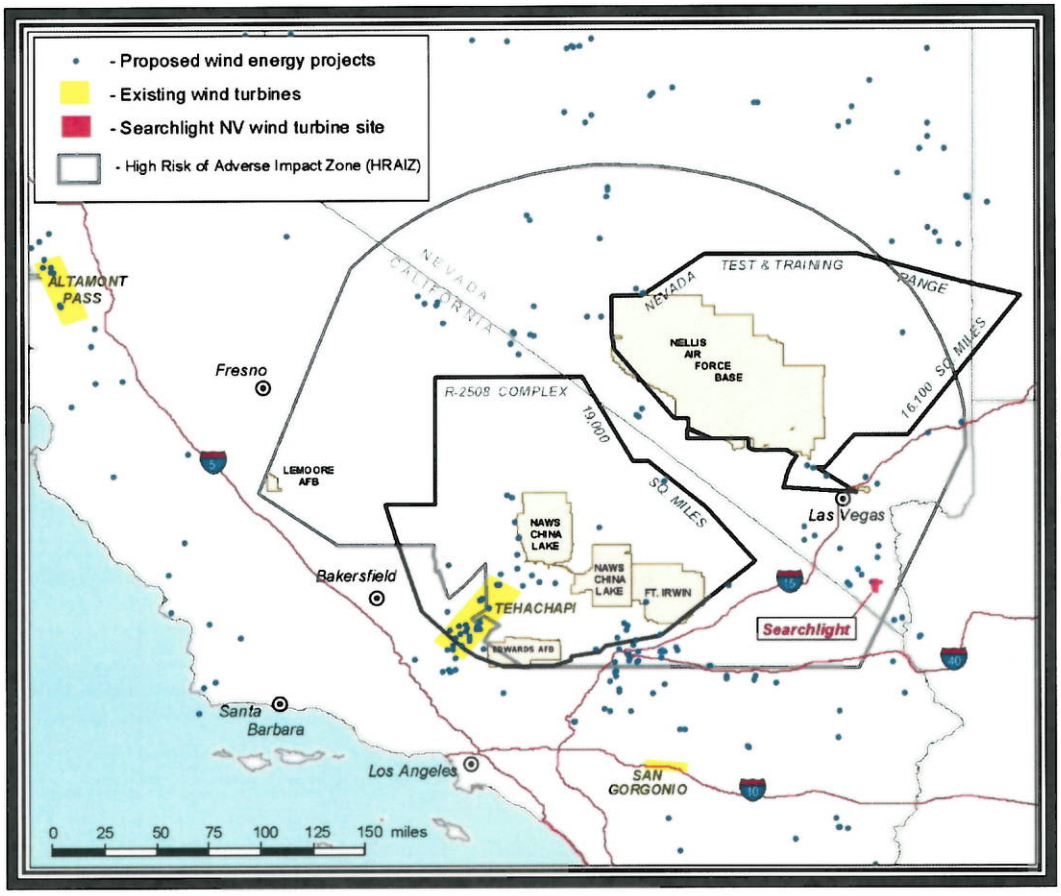

Figure 2: Existing Wind Turbines and Proposed Wind Turbine Development Sites

As previously mentioned, the impacts to the airborne radar test mission were clearly demonstrated during the 2009 NAWCWD flight test program and further verified by the 2011 Air Force Flight Test Center multi-airborne radar platform tests. These test results, along with state of the art computer modeling, conclusively demonstrated that wind turbines operating within the airborne radar test environment induce undesirable and unpredictable variations in test data measurements, making it difficult (if not impossible) to verify system performance, such as specification testing. Wind turbines degrade the airborne radar's ability to detect targets as:

- Their operation affects all pulse Doppler radar systems by corrupting the returned spectrum

- Spectral corruption impacts to radar modes may differ

The undesirable and unpredictable variations in impacts are caused by the mimicking or masking effect of the turbines on the intended target, which varies according to the orientation of the wind turbines, distance to the wind turbines, wind turbine speed, and other operational factors. Wind turbines are highly reflective objects and the angular velocity of their rotating blades is detected by Doppler radar as flying objects. The radar detects speeds up to the maximum tangential tip speed of the rotor (60-70 meters/second), which is similar to an aircraft in flight. These phenomenon produce radar returns that are larger and move faster than many of the targets the Navy attempts to validate and that an airborne radar system is capable of identifying and tracking. In addition, the energy return from wind turbine blades can confuse a radar system and cause it to dedicate excessive amounts of processing power on false targets at the expense of detecting real targets within specification requirements. These combined effects contaminate the intended target return signal and raise the noise floor causing an:

- Interference with the radar and pilots' ability to detect actual targets
- Increased processing time (due to tracking false targets) and not satisfying specification requirements
- Inability of the radar to acquire actual targets
- Inability to field weapons systems to warfighters

If wind energy development expands into currently undeveloped areas in and around the R-2508 Complex, NAWCWD would be unable to verify radar specification performance or conduct other types of developmental testing due to corrupted test data. The NAWCWD mission would be impacted by:

- Reduced ability to validate performance of radar systems delivered to the warfighter
- Loss of rapid response capability for some radar systems
- Challenges to fielding new/upgraded radar systems

4. Proposed High Risk of Adverse Impact Zone for Airborne Radar Testing

The HRAIZ concept is an outgrowth of the NDAA 2011 Section 358 which directs the Secretary of Defense to "identify geographic areas selected as proposed locations for projects filed, or which may be filed in the future, with the Secretary of Transportation pursuant to section 44718 of title 49, United States Code, where such projects could have an adverse impact on military operations and readiness and categorize the risk of adverse impact in such areas as high, medium, or low for the purpose of informing early outreach efforts".

The HRAIZ was developed using a methodology that sought to protect all current and future flight test requirements. Various sizes and configurations were examined with the goal of minimizing the impact on wind energy development while simultaneously protecting the airborne radar test mission. When the first boundaries of the HRAIZ were defined, an area of

approximately 400 x600 nautical miles was identified, but was soon deemed impractical because of its tremendous size. The size of the HRAIZ was trimmed to the absolute minimum airspace required for completing flight tests by considering the following factors:

- The electronically steered radars currently being developed and upgraded sweep 70 degrees to either side of center of the aircraft flight track. Therefore, it is important to have an area of that azimuth free from radar interference to satisfy testing requirements.
- The radar return from a commercial scale wind turbine is approximately the same as a low-observable target at 140 nautical miles based on test data and modeling. Therefore, to avoid impacts to radar testing, the area 140 nautical miles in front of the test aircraft must be free of wind turbines.
- The test area must be increased by 120 nautical miles to accommodate "shooter" and "target" engagement as the test aircraft and targets move. This provides the minimum engagement distance required for test setup and data acquisition during target engagement.
- A single flight track was selected to minimize the area, although multiple flight tracks would be ideal to minimize test constraints and scheduling complexities for both the Navy and Air Force.

The net result is the proposed HRAIZ shown in Figure 3.

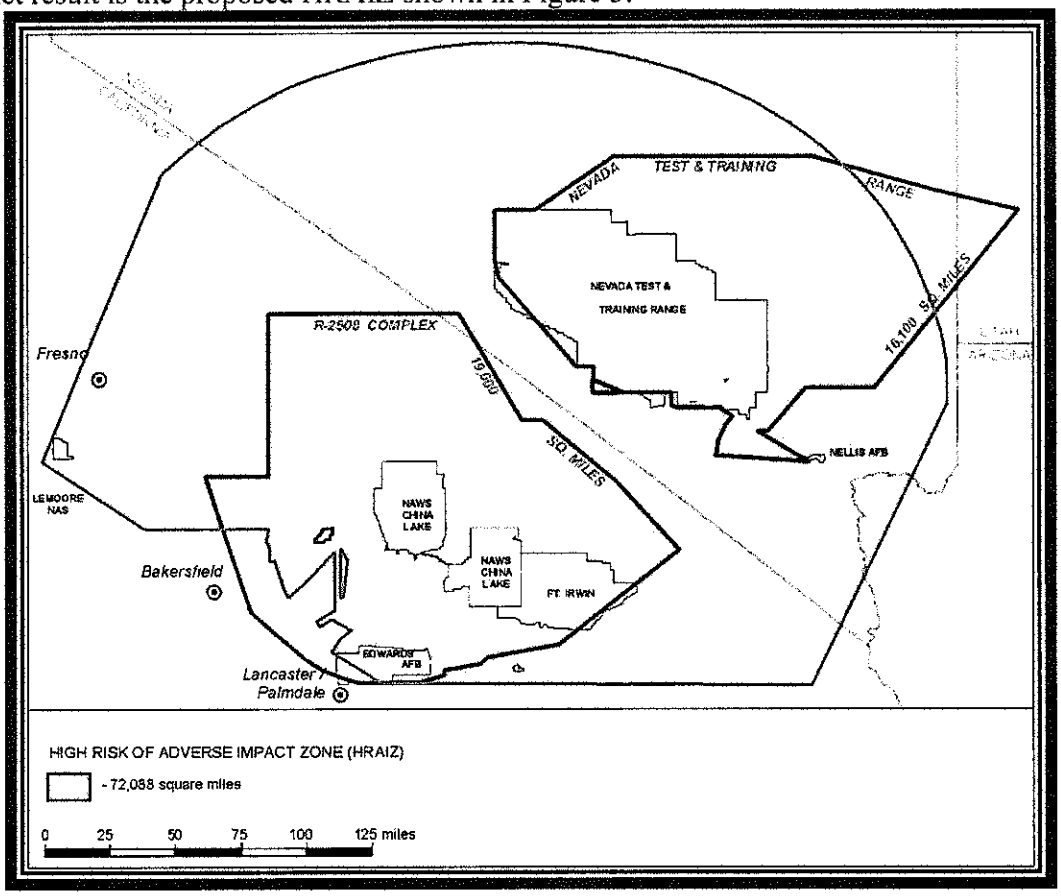

Figure 3: Proposed HRAIZ

The "cutout" in the southwest corner of the HRAIZ accounts for the existing wind turbines in the Tehachapi wind resource area and is configured consistent with the existing Kern County ordinance that limits where and how high wind turbines can be built relative to military mission impacts. The proposed HRAIZ is a large area, but when broken down into a more definitive description of the land use/ownership and the development potential, it becomes apparent that only a small percentage of land area has the potential for development of current wind turbine technologies. Figures 4, 5, and 6 demonstrate this point.

Figure 4 indicates more than half of the proposed HRAIZ (38,373 square miles) encompasses land upon which wind energy development is highly unlikely due to the land being a DoD installation, wilderness area, wilderness study area, or national park.

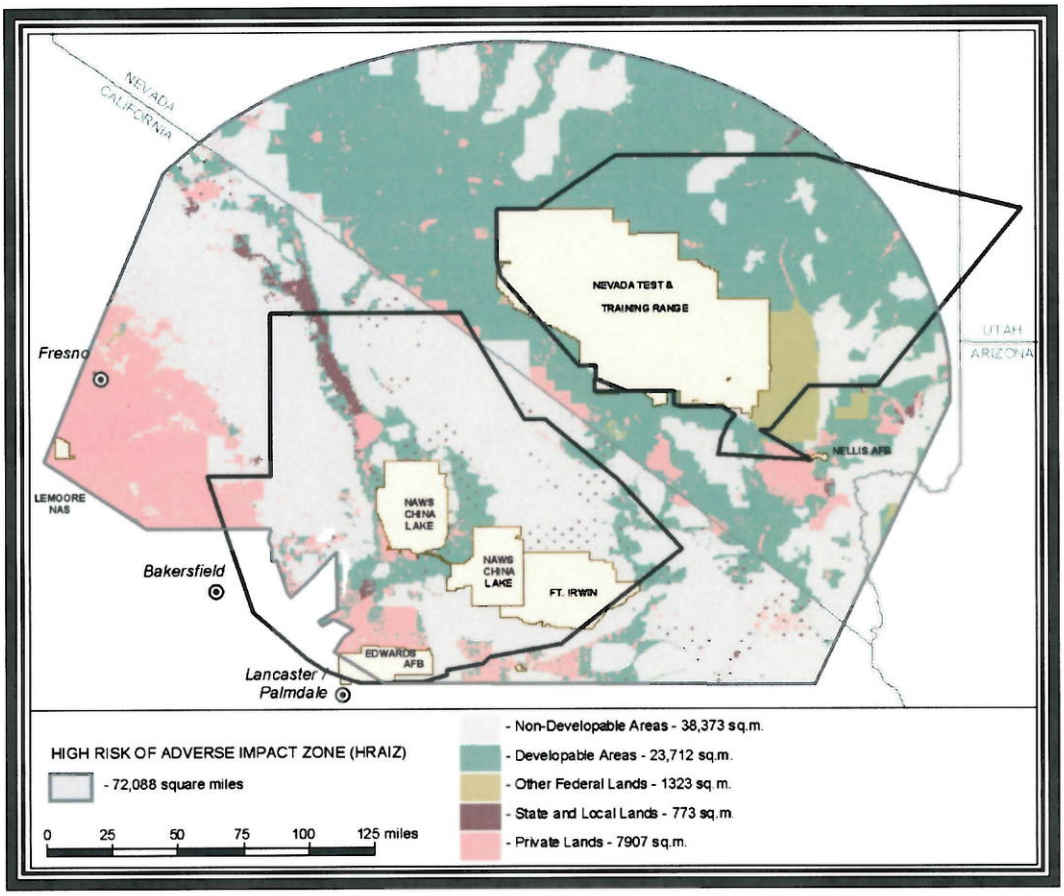

Figure 4: Land ownership within the HRAIZ

In addition, to support development of current wind turbine systems, a requirement for Class 3 and above wind resources is assumed. As shown in Figure 5, these wind resources are concentrated in the southern portion of the HRAIZ but are also scattered throughout other HRAIZ areas in smaller but potentially developable patches.

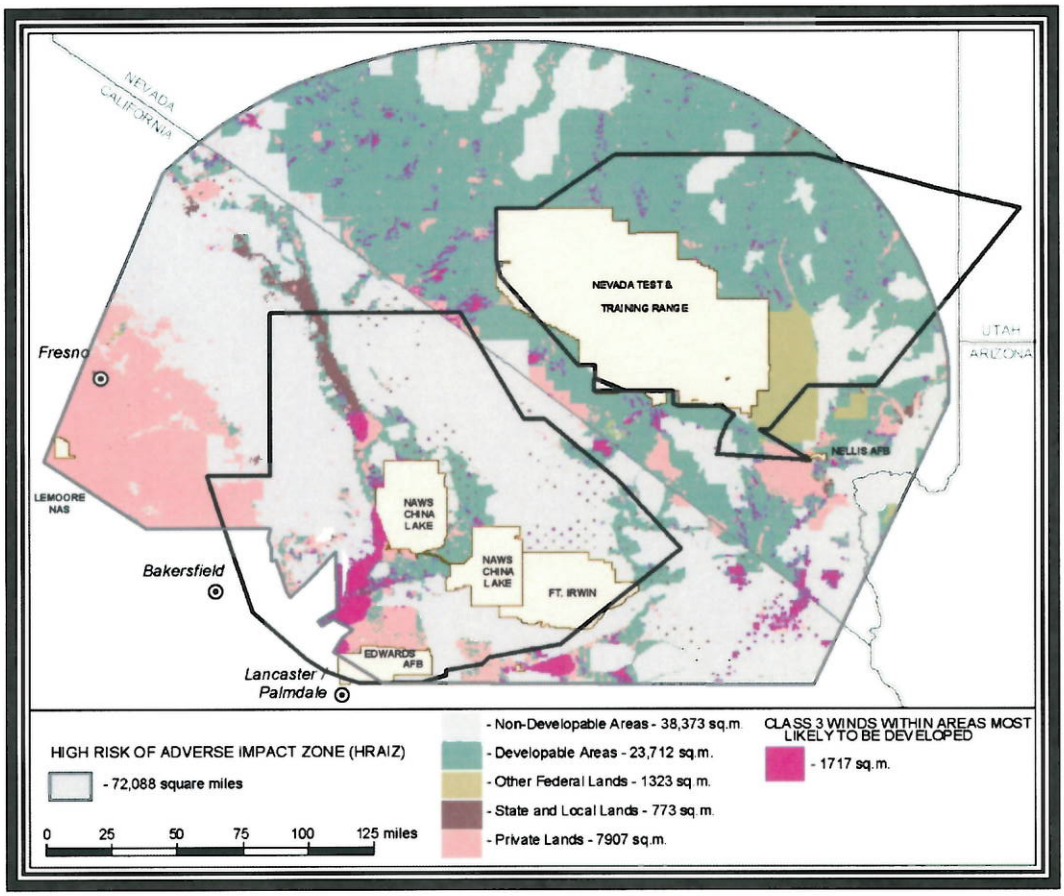

Figure 5: Class 3 and Above Wind Resource Areas

Using this assumption, it was determined that only 1,717 square miles of the proposed HRAIZ would be feasible for development. That area is reduced even further if proximity to existing transmission lines is taken into account, because many of the Class 3 wind areas are several hundred miles from existing transmission lines, as shown in Figure 6.

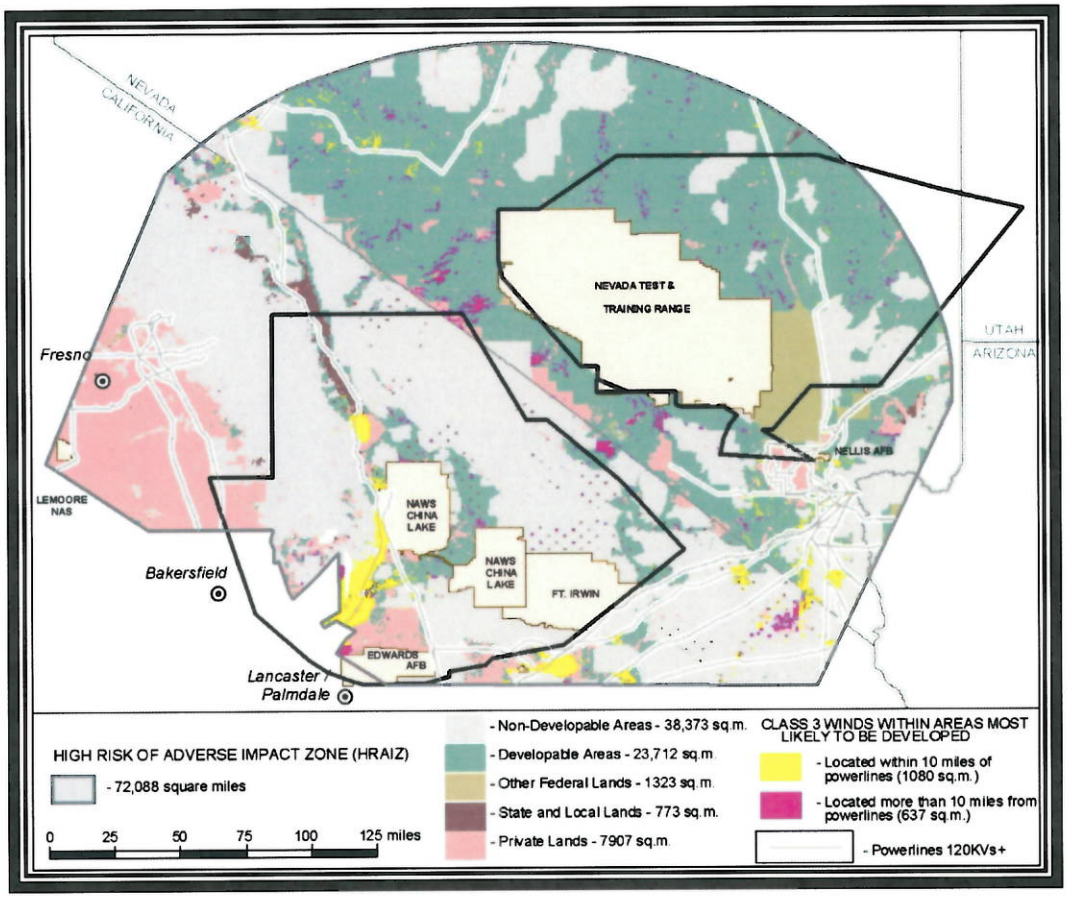

Figure 6: Transmission Lines Relative to Class 3 and Above Wind Resource Areas

Considering the expense and regulatory challenges of tying multiple wind energy projects into these distant existing high voltage lines would be too high to justify, the total developable areas with both Class 3 and above wind resources and within ten miles of transmission lines is only 637 square miles (~0.9 percent of the total proposed HRAIZ). Additionally, if local restrictions and zoning ordinances are taken into account, that number becomes even smaller.

Although wind energy development on the majority of the proposed HRAIZ land area is unlikely, the Navy has determined it necessary to establish the HRAIZ for the following reasons:

- The possibility of one or more wind turbines constructed in the HRAIZ presents a threat to the NAWCWD mission.
- Even a single wind turbine constructed in a remote area can potentially negate the ability to conduct certain radar testing over a large area.
- Areas considered low potential for wind energy development today may become higher potential areas in the future due to constantly improving wind energy technology.
- The established protective area will allow the Navy to continue its mission today and into the future.

- A clear demarcation of what locations the Navy will or will not object to regarding wind development will be identified.
- The compatibility of solar energy systems, including photovoltaic and concentrated solar power, with the current and foreseeable future NAWCWD mission will continue to be emphasized.

5. MIT Lincoln Laboratory Validation

In April 2012, OSD contracted MIT LL to review the NAWCWD flight test results, data, and conclusions. In June 2012, OSD modified the scope of work to include recommendations to mitigate impacts of proposed wind energy projects in the Searchlight, Nevada area (shown in Figure 2). MIT LL validated the NAWCWD effort and confirmed that wind turbines in the proposed HRAIZ would negatively impact the airborne radar test mission. MIT LL also proposed three measures that, if technically and operationally feasible, could mitigate the impacts of wind turbines near Searchlight. They include:

- Reducing the size of the HRAIZ to avoid the Searchlight area
- Relocating the HRAIZ to avoid the Searchlight area
- Removing wind turbine corrupted data during post test processing.

MIT LL clearly indicated that no analysis of the technical or operational feasibility of the proposed mitigation measures had been conducted. NAWCWD considered these and other mitigation options as described in the next section.

6. Mitigation Analysis

MIT LL concurs with NAWCWD that airborne radar testing will be significantly impacted by any wind turbines operating within the HRAIZ. Mitigating the wind turbine problem is complicated by the multitude of radar system types. Mitigation that works for one type of radar does not necessarily work for another. The following mitigation measures, including those suggested by MIT LL specifically for the Searchlight project, were considered but rejected because of high technical risk and uncertainty of their effectiveness:

- Reduce wind turbine radar signature (stealth turbines): very high technical risk because there are no wind turbine developers currently manufacturing stealth turbines. Even if constructed, the potential for stealth turbines to eliminate a wide range of frequencies is improbable.

- Reduce turbine blade tip speed: very high technical risk because slowing down the turbine speed to sufficiently eliminate radar detection reduces the speed below the minimum levels required to generate power.

- Reduce size of the HRAIZ: high risk because it is unfeasible to reduce wind turbine impacts to an acceptable level. Considering NAWCWD already orients flights away from the Tehachapi wind resource area, it would be increasingly difficult to control flight

scenarios to avoid wind turbines. In addition, reducing the size of the proposed HRAIZ would negate NAWCWD's ability to conduct radar specification tests to the manner prescribed in the applicable system specifications.

- Relocate the HRAIZ: high risk because the proposed HRAIZ was selected to minimize impacts on high wind resource areas. Moving the HRAIZ would eliminate the impacts of the Searchlight project but, in turn, impact other wind energy projects. In addition, the test infrastructure is already in place and relocating the HRAIZ would require relocation of one or more systems, which is cost prohibitive. These systems allow for multiple tests during a single test event, encouraging efficiency and concurrent test points across multiple test and evaluation flights.

- Remove wind turbine corrupted data during post test processing: high technical risk and high impact on the NAWCWD test team's ability to monitor real time test results. Real time results are an important requirement for cost-effective flight testing and keeping acquisition programs on schedule. Additionally, removing wind turbine data may not be technically possible with current radar systems.

- Perform testing at alternative test sites: high risk because the NAWCWD RDAT&E mission is non-severable. Airborne radar testing cannot be conducted elsewhere without relocating much of the capability of the CLR and greater R-2508 Complex infrastructure.

7. Conclusion

The Navy and MIT LL concur that airborne radar testing will be significantly impacted by any wind turbines operating within the proposed HRAIZ. This conclusion is supported by detailed analysis of flight test data and computer modeling at both the classified and unclassified levels.